Natural System Model (NSM) Version 4.5

Introduction

Prior to the major drainage activities that began early this century, the Everglades consisted of 3 million acres of subtropical wetlands that covered much of South Florida. The Everglades region was characterized by an extremely low gradient, heterogeneous landscape mosaic that evolved over 5000 years (Science Sub Group Report, 1993). This immense wetland system south of Lake Okeechobee sprawled from the south shore of Lake Okeechobee to the mangrove estuaries of Florida Bay and Gulf of Mexico. The Immokalee Ridge to the west and the coastal ridges to the east generally mark the hydrologic boundaries of the historic Everglades, although numerous connections through the coastal ridge overflowed from the Everglades to the Atlantic Ocean. The primary characteristics of the pre-drainage wetland ecosystem in the Everglades were the hydrologic regime that featured slow sheetflow and natural recession due to storage, large spatial scale, and heterogeneity in habitat.

The Natural System Model (NSM) simulates the hydrologic response of a pre-drained Everglades system. The NSM does not attempt to simulate the pre-drained hydrology. Rather, more recent climatic data is used to simulate the pre-drained hydrologic response to current hydrologic input. Although one may wish to recreate the hydrologic conditions of the late 1800's or early 1900's, the input data necessary to perform such a simulation do not exist. The use of recent input data, e.g. rainfall, potential evapotranspiration, tidal and inflow boundaries, allows for meaningful comparisons between the current managed system and the natural system under identical climatic conditions.

The landscape of present day south Florida has been greatly affected by the land reclamation, flood control and water management activities which have occurred since the early 1900's. The complex network of canals, structures and levees in the current system are replaced in the NSM with the rivers, creeks and transverse glades which were present prior to the construction of drainage canals. The vegetation and topography used by the NSM are based on pre-drainage conditions. The landcover simulated by the NSM is static, i.e. the model does not attempt simulate vegetation succession.

The use of the NSM is closely linked to the South Florida Water Management Model (SFWMM). The SFWMM is a regional scale hydrologic model that simulates the hydrology and highly managed water system in south Florida. The design of the SFWMM takes into consideration south Florida's unique hydrologic processes and geologic features, including the integrated surface and ground water hydrology and the operation of the Central and South Florida (C&SF) Project. The NSM uses the same climatic input, model parameters and computational methods as the SFWMM. Physical features, such as topography, vegetation type and river locations are adjusted to represent the pre-drainage condition. Since traditional calibration/verification methods can not be applied to the NSM, model parameters are based on the calibrated and verified SFWMM.

Physical Data

The NSM encompasses an area from Lake Istokpoga to Florida Bay. The western boundary extends southward from Lake Istokpoga to near the Gulf of Mexico, and continues along the coastal marsh fringe, turning southward to Shark River Slough and Florida Bay. The eastern boundary extends across the northern Indian Prairie Region to the Kissimmee River, and continues around the northern rim of Lake Okeechobee and turning eastward to the Atlantic Ocean. The eastern boundary follows the coastline southward to Biscayne Bay and Florida Bay. The model domain is divided into 2328 2-mile by 2-mile square mile grid cells. Vegetation class, land surface elevation and aquifer parameters are assigned to each cell and are assumed uniform within each cell.

The vegetation coverage is based on the estimated landscape of the pre-drained Everglades by McVoy and Park (Figure 1). Eleven landscape types are identified, based on an evaluation of hydrology (water depth, hydroperiod, flow direction and velocity), vegetation community, soil type and topographic relief. The NSM uses vegetation based parameters to compute evapotranspiration (ET) and overland flow. The use of SFWMM parameters implies that the ET and flow characteristics of the current landscape are comparable to the pre-drainage landscape and transportable, e.g. parameters calibrated in the Everglades National Park can be applied to areas outside of the Park boundaries.

Of the eleven pre-drainage landscape types, seven have been identified in the current system, including mangroves, forested uplands, marsh, sawgrass plains, wet prairie, shrubland and forested wetlands. Parameter values for the non-existent types (ridge and slough, marl marsh, edge marsh and grassland) are based on the landscape they most closely resemble in the current system. The ET characteristics of the R&S landscape most closely resemble the modified ridge and slough of central Water Conservation Area 3A, and the flow characteristics most closely resemble the modified ridge and sawgrass invaded slough in Shark River Slough. The vegetation and flow characteristics of the marl marshes on either side of Shark River Slough most closely resemble the marl prairie now found in those same areas. Edge marsh and grassland most closely resemble the wet prairie and shrubland landscapes identified in the current system.

Surface elevations in the NSM approximate the pre-drainage topography in south Florida. In general, land surface elevations are consistent with current land surface elevations except in areas impacted by soil subsidence. Land surface elevations in the Eastern Flatwoods, Loxahatchee Slough, Atlantic Coastal Ridge, Miami Rock Ridge, Everglades National Park, Big Cypress and Lake Okeechobee are consistent with the SFWMM. Land surface elevations in other non- subsidence areas, including Immokolee Ridge, Caloosahatchee River basin, Fisheating Creek and Istokpoga / Indian Prairie regions are estimated from USGS and COE sources.

The most severe soil subsidence occurred along the Okeechobee Rim, Central Everglades and Northern Transverse Glades regions. Land surface elevations in these areas are based on land surface profiles which were surveyed during, or prior to the construction of the drainage canals (Figure 2).

Aquifer parameters (depth, permeability and soil storage coefficient) are consistent with the SFWMM. In areas outside the SFWMM boundaries, aquifer depth and permeability are based on published well log data.

The location of rivers, creeks and transverse glades is described through a series of x-y coordinates. The location of these pre-drainage flowways is based on government survey plats (completed between 1855 and 1870) and the SFWMD Primary Hydrography Coverage. River cells and associated river segments are identified by the intersection of the grid cell mesh with the river coordinates.

Time Variant Data

The hydrology of south Florida is primarily rainfall driven, and highly influenced by other hydrologic processes, e.g. ET, overland and ground water flow. This phenomena is simulated in the NSM by applying external stimuli (rainfall, potential ET and boundary flow) to affected cells and moving water between cells in response hydrologic processes.

The NSM utilizes a rainfall database which contains daily estimated rainfall for each cell in the respective model domains. Estimates for each cell are based on rainfall data collected at the station nearest to the cell center. Rainfall data from 671 stations in ten counties were used to

develop the database.

Daily potential ET is computed for eleven stations using the a modified Penman - Monteith Method (Giddings and Restrepo, 1994). An inverse distance method is used to weigh the contribution of each station to each cell.

Daily inflow along the northern boundary are defined by a series of inflow points into Lake Istokpoga and Lake Okeechobee. These flows represent the "natural" inflow which would have occurred under pre-drainage conditions. The Lake Istokpoga and Fisheating Creek basins have not been greatly altered by water management projects, such as lake regulation schedules, channelization, and impoundments. The rainfall-runoff relationship is assumed to be comparable to pre-drainage conditions, and natural inflows from these basins are approximated by observed flows at Arbuckle Creek, Josephine Creek, ungaged local inflow at Lake Istokpoga, and Fisheating Creek.

The Kissimmee River basin has been affected by a number of water management projects, including the connection and regulation of lakes in the upper basin, and channelization of the Kissimmee River. Natural inflow from the Kissimmee basin is estimated using a rainfall-runoff model, calibrated to the earliest available flow data (1934-1942). A set synthetic flows are generated using 1965-1995 rainfall and potential ET data. Inflow from peripheral basins north of Lake Okeechobee (Nubbins Slough, Taylor Creek and S154), are assumed to be proportional to the lower Kissimmee basin runoff.

Tidal boundaries are effectively flow boundaries, in that water is removed or added as water levels are adjusted to coincide with the tidal stage. Tidal boundaries are established in ocean cells, which include cells along the Atlantic Ocean and Florida Bay. Tidal stages are based on long term monthly average tide data at six tidal gaging stations along the Atlantic Ocean, Biscayne Bay and Florida Bay.

Hydrologic Processes

Water is distributed within the model domain by a set of hydrologic processes. Processes are modeled independently within each time step, with more transient phenomena computed before less transient phenomena.

Vertical movement of water within a cell is simulated by infiltration and ET processes. The infiltration process simulates the downward movement of water from surface water ponding to the water table. The ET process simulates the release of water from surface water ponding and ground water table to the atmosphere through evaporation and plant transpiration, respectively.

The overland flow process simulates surface water movement between adjacent cells. The NSM uses an explicit, finite difference method to solve the overland flow equations. No-flow boundaries are established for the non-ocean cells along the northern, eastern, and most of the western limits of the model domain. Fixed head boundaries based on the tidal stage are imposed in ocean cells. Fixed gradient boundaries are imposed in cells along the southwest boundary. Lake Okeechobee, Lake Istokpoga and Lake Hicpochee are treated as level pools, wherein an "equalizing" function computes average stage for each lake and uniformly imposes this stage in the respective lake cells.

Ground water flow is simulated by solving for ground water level in a finite difference approximation of the linearized two-dimensional, transient, subsurface flow equation for unconfined aquifers. A zero gradient ground water boundary condition is established along the perimeter of the model domain. The head values in ocean cells coincide with stages established by the tidal boundary.

The river flow process simulates the influence of rivers on water levels. Rivers are represented

as storage volumes in the model. Downstream discharge can be released to a cell, defined as inflow to another river, or removed from the model (tidal release). An iterative bisection technique is used to compute the river stage for which net inflow is equivalent to change in storage.

Results

The hydrology of the pre-drained Everglades is dominated by surface water processes, driven by rainfall and ET. Water generally moves as surface water slowly from north to south in response to the low land surface water gradient (Figure 3). The large storage capacity of Lake Okeechobee, coupled with its long overflow perimeter provides the buffering capacity required to transform large lake inflows into a slow moving, low gradient release to the south. Within the Everglades boundary, the magnitude of the overland flow vectors are uniform with a south to southeast direction in the upper/central Everglades. The relative magnitude of the overland flow vectors begin to concentrate in what is now Water Conservation Area 2B. This concentration continues through the northern transverse glades area south to Shark River Slough and southwest towards the Gulf of Mexico.

Water levels are uniform throughout the upper and central Everglades with median ponding depths of 0.5 to 1.0 ft (Figure 4). Water levels are more variable in the lower Everglades with depths up to 4 ft in the northern transverse glades region, 2.0 ft in Shark River Slough, and 0.5 ft above to 0.5 ft below land surface in the marl wetlands in ENP. Outside the historic Everglades boundary, median water levels are generally near land surface to more than 4 ft below land surface along the Atlantic Coastal Ridge and the Highlands Ridge.

Water levels within the Everglades boundary generally fluctuate between 2.0 to 2.5 ft annually, with a somewhat smaller range (1.75 ft) in Lake Okeechobee, Hillsboro Lakes and Shark River Slough (Figure 5). Water levels in virtually all of the Everglades drop below land surface at some point during the simulation. Conversely, virtually all of the Everglades have extended periods (< 12 months) of inundation. Under these "wet" conditions, annual low water ponding depths of 0.5-1.0 ft and 2.0 ft persist in the upper/central Everglades and Shark River Slough, respectively.

Although much of the Everglades is subject to annual low water levels which drop below land surface, the duration of the dry down is very short. The median number of days of inundation per year or "hydroperiod" for the Everglades is generally greater than 330 days/year (Figure 6). Even under very dry conditions, hydroperiods in the upper/central Everglades are generally greater than 150 days/hr and hydroperiods in the Shark River Slough to the northern transverse glades area still exceed 335 days/yr.